Parts Standardization and Management Committee (PSMC)

Lead-free Update

April 26-28, 2016

McLean, VA

IPC PERM Council

Meeting Info

- Location: Phoenix, AZ
- Host: Honeywell
- Date: Feb 23rd – 25th, 2016

Leadership

- (Raytheon) - Chair
- (Boeing Company) - Vice Chair, Industry
- (U.S. Army Aviation & Missile Command) – Vice Chair, government

Highlights

- Standard Reliability Test Vehicle
  - PERM will recommend/endorse a test vehicle(s)
  - Evaluation/comparison is underway
  - IPC B-series, PCQR2
- Process Qualification Test Vehicle (Foresite)
  - Evaluation of PbFree solders & finish compatibility
    - Reflow, selective, wave, etc.
    - Cleanliness, SIR
    - X-section: BGA, QFN, PLCC
- AVSI In-Service Reliability Program (Honeywell)
  - Intent: Measure in extreme conditions in/out pressure vessel in commercial and military fixed wing & rotary
  - 4 categories : Lead Free, small comp (semiconductor), Single event effect, wire bonds
- SERDP Project: Layer Coating (BAE)
  - Whisker mitigation thru conformal coat, including evaluation of nanoparticle enhanced coatings
  - Conclusion: functionalized nanoparticles in urethane improve mech prop & whisker mitigation

Highlights (Cont)

- Tin Self-Mitigation (Raytheon)
  - Phase I: package geometry and solder process are significant factors. Pad size and printed board size are not important factors. Table available with probabilities of self-mitigation by package and assembly process.
- Whisker Take-aways (see next slide)
  - Coming soon - a progression of ways that we can look at tin whisker mitigation
  - Self-mitigation, conformal coat, and modeling risk
- Mixed Alloy BGA vs. Reballing (CALCE)
  - If you do both well they do not compromise reliability
- Much time devoted to review of draft Pb-free Design Guide

Concerns

- **Supporter Bandwidth:** bandwidth to support task groups. Volunteers were minimal.
- **J-STD-001**: There was talk of LFCP requirements incorporation into J-STD-001. Need to assess the business impact internally.

New Approaches for Whisker Risk

- Comprehensive, progressive approach to tin whisker mitigation & risk analysis
- Step 1 – Self-mitigation analysis
  - Raytheon lead sub-team; "contamination" of tin plating with SnPb solder, identifying parts mitigated 100% & percentages of those with partial mitigation
- Step 2 – Conformal coat validation
  - Validate conformal cost coverage/areas with gaps in conformal coat; correlate gaps with areas with "self-mitigation" from step 1
  - "Most surfaces not covered by self-mitigation are readily coated"
- Step 3 – Risk model for remaining unmitigated surfaces
  - For surfaces not mitigated by step 1 and step 2, run risk model to determine probability of tin whisker short (presented by Rockwell Collins; considers spacing, surface areas, whisker length distributions (based on case studies), different surface orientations, etc.
- Studies for these steps are maturing, but ongoing. Future standards may come from these.

Alternate slides

Standard Reliability Test Vehicle Matrix

Test vehicle board designs for baseline and periodic lead-free manufacturing process qualification

- Developing existing test vehicle profiles
- Researching additional public domain test vehicles
- Initial evaluation matrix developed in Excel format.
  - Format is useful for selection purposes, but unwieldy for more detailed information.
- New format agreed
  - Leverage the format created by Foresite.
  - Key content includes advantages, disadvantages and applicability (best use).

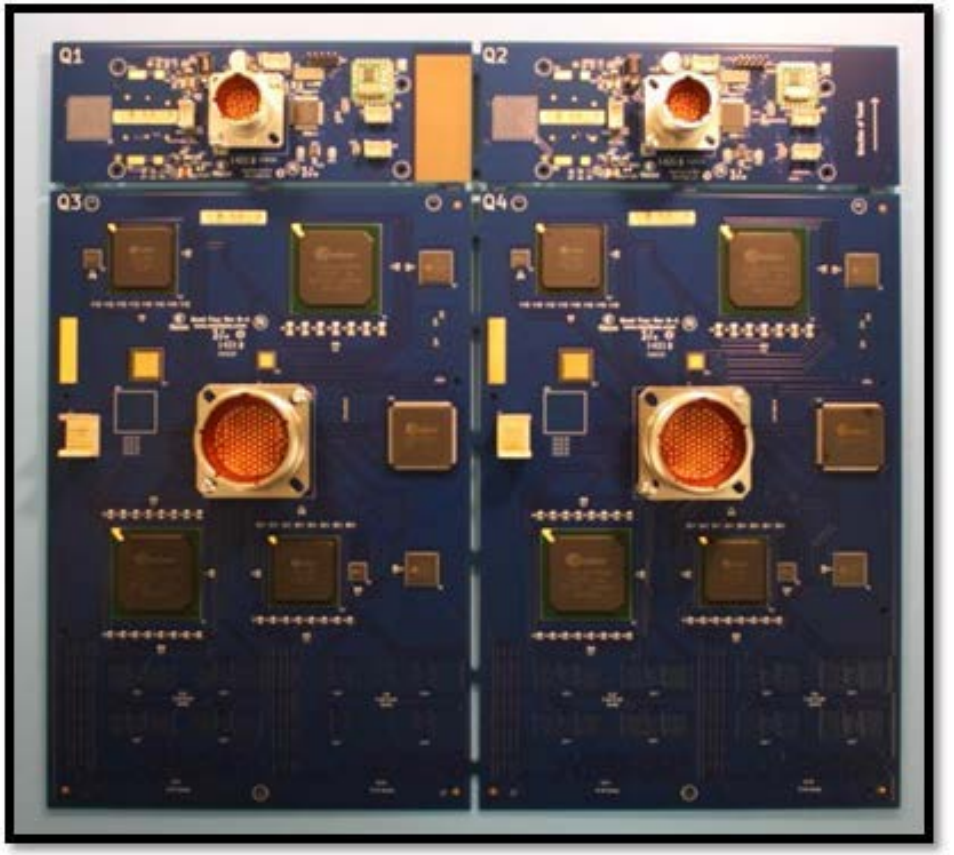
	Test Vehicle Performance Requirements																		Component Packages												Component Function/Technology									Test Vehicle General Characteristics									
Test Vehicle	Full Process Evaluation	SIR IPC	SIR Bellcore	CAF	Electromigration	Bellcore TR-78/GR-78	Adhesion Testing	Dielectric Testing	Soldermask Interactions/effects	Cleaning/Cleanliness Testing	Temperature	Vibration/Shock	Drop	Rework/Manual Soldering	Interconnect Stress Test (IST)	PCB Laminate Substrate	Copper Dissolution		PLCC	LCC	SMT Passive	BGA	BTC ==> QFN, LGA, MLF, DFN	QFP/TQFP	CSP	HDI	DIP	Radial/Axial Through Hole	Through Hole Connector		RF	Microprocessor	MEMs	LEDs	HDI					Ease of Assembly	East of Test	Assembly Costs	Component Costs	Correlation to B-24	Correlation to B-25	Correlation to B-36	Deep Historical Database	Real world relavence	SMT	Wave Solder/Thru-hole
Foresite Umpire																																																			
IPC-B-24																																																			
IPC-B-25																																																			
IPC-B-25A																																																			
IPC-B-36																																																			
NASA DoD Phase 2																																																			
NASA DoD Phase 3 Board 1																																																			
NASA DoD Phase 3 Board 2																																																			
IPC-9253 / IPC-9254 / PCQR2																																																			
SMTA Saber																																																			
Practical Components PC031																																																			
Flextronics BTC Test Vehicle																																																			

Joint Industry and Government

Standard Reliability Test Vehicle Questions, Next Steps

- Should test vehicle comparison/applicability matrix be:
  - integrated in to the LF Design Guide and/or a revised 0005-3?
  - a PERM document that is maintained and included in other standards as a reference?
- Create profiles for additional test vehicles
  - Survey will be sent to PERM to solicit additional candidate test vehicles
- Revise spreadsheet matrix to function as an applicability/selection appendix.

Foresite Test Vehicle & Process



PCB Test Process Flow
Leaded or Lead Free Solder Chemistry

Zero Hour Pre-Test Inspection
Visual compliance to **IPC 610-E**
Photo Image Documentation
C-3 Cleanliness data
Continuity and Electrical Function

Pre-Conditioning
GEIA-STD-0005-3 Section 4.2 & 5.2.3
Isothermal Aging at 100C/96 hours
or 85C/332 hours.

Vibration Shock Testing
Mil-Std-810G Method 516.7 procedure 1.
Z Axis Shock Test at 20 g's for 11 msec.
Sine Sweep per JEDEC Std. Service Condition 3

Random Vibration -Mil Std-HDBK-2164A

Thermal Cycle - JESD22-105C condition A (-55 + 125C 750 cycles minimum)

Humidity -JEDEC Std 033C, JESD 201A (ramp to 40C/95%Rh/120hrs).

Continuous SIR per IPC 2.3.3.7 at 40C 90% RH.

Mechanical Testing following Environmental Conditioning

Visual compliance to **IPC 610-E**
Evidence of Tin Whiskering **JESD-201A**
Cross Section components and PCB areas of interest
X-Ray selected areas of interest
C-3 selected area of interest
Complete Electrical continuity and isolation Testing

*Component Shear Testing Optional

Parts Standardization & Management Committee
Joint Industry and Government

Foresite Conclusions

- It can be concluded in this experimental matrix, and from this small sample, that if BGAs are used in a level 3 design, Pb chemistry is still likely to be more robust in harsh use environments. Design considerations which would isolate vibration and board strain could be employed as a means of improving the performance of Pb-free BGA components. These design improvements could be initially modeled by FEA then tested on hardware in future studies.
  - Testing included pre-conditioning, vibration shock, random vibration, 1000 temperature cycles and humidity exposure

AVSI In-Service Reliability Program

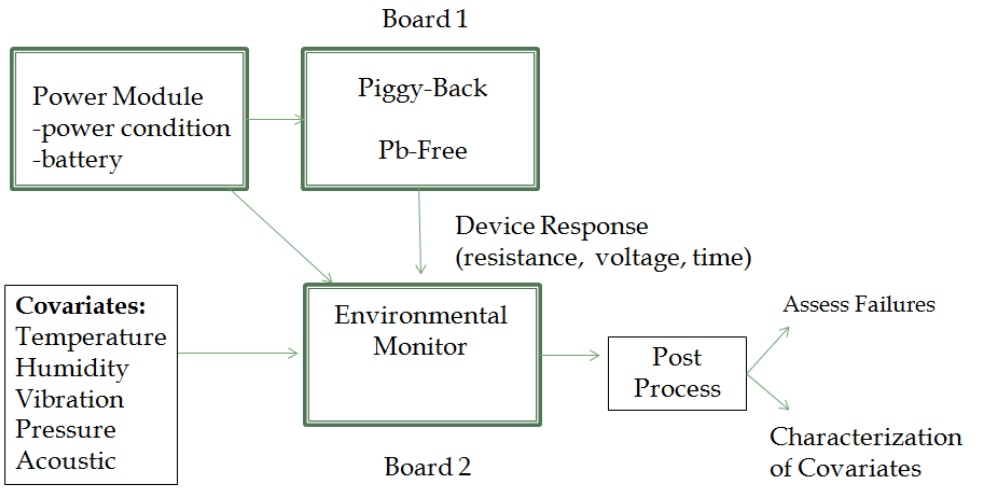
- Focus on establishing the real-world avionics environment
- Airplane Environment Monitor (AEM) Project
  - Early (1998) AVSI Project
  - Qualified environmental monitoring hardware
  - Collected data in flight deck and EE bay on passenger airliners on commercial routes

- Allowed measurement of in-service values of temperature, pressure, and humidity inside the pressure vessel over various flight profiles

AVSI Project Status

- **Phase I – ISRP Planning project is launched**
  - Develop Technical and Management Program Plans for full ISRP
  - Conducting lead-free risk analysis
  - Developing requirements for semiconductor Wear-out testing, SEE testing, and Wire Bonds
  - Develop requirements and partners for flight tests
- **Program Management team meeting once a week & Sub-Group meetings initiated**
- **Participants include Airbus Group, Boeing, Celestica, Embraer, Foresite, GE Aviation, Honeywell, Saab, FAA, and DoD**

Architecture



DoD/EPA/DOE SERDP WP-2213: Novel Whisker Mitigating Composite Conformal Coat Assessment

- **Performers: BAE Systems (PI);**
  - Celestica, Bayer Material Science, Henkel Electronics, Binghamton University
- **Technology Focus**
  - Develop and evaluate nanoparticle filled conformal coatings designed to provide long term whisker penetration resistance and coverage on tin rich metal surfaces prone to whisker growth in commercial lead-free electronics used in modern DoD systems.
- **Research Objectives**
  - Identify the fundamental mechanisms by which conformal coatings provide long-term tin whisker penetration resistance and inhibit nucleation/growth. Correlate mechanical properties and coverage thickness to whisker penetration resistance.
- **Project Progress and Results**
  - Functionalized nanosilica and non-functional nanoalumina enhanced polyurethane conformal coatings have shown improved spray coating coverage characteristics and crack resistance during thermal cycling fatigue testing. Lead-free assembly whisker mitigation validation testing is in process.
- **Technology Transition**
  - Current project partners provide coating materials to industry. SERDP test data will be considered during updates to the DoD adopted IPC standards for coating materials and coverage.

WP2213 Coating development

Nanoparticle suspension and coating formulation

Nanoparticle filled vs. non-filled properties characterization

Whisker testing

Layered coating characterization and testing

Rework capability assessment

Model development and validation

Solvent based polyurethane

Low/Non-solvent polyurethane-acrylate (2014-2015)

Hurdle – nanoparticle supplier change
Re-do microstructural characterization and need to re-do properties

Best coating

Layered coating whisker testing in process

WP2213 Coating Conclusions

- Functionalized nanoparticles in urethane coating improve mechanical properties and whisker mitigation
  - Even dispersion and no agglomeration obtained after cure on 3D assembly lead geometry
  - Prior work showed that improved methods for mechanical characterization were needed to obtain properties needed for whisker mitigation (beyond the “data sheet”)
- Low viscosity dip helps coverage in “spray blind spots”
  - Process development needed to reduce bridging between leads
- 2 Spray improved thickness over 1 spray
  - PC18M exhibited hazy surface due to surface microbubble ruptures
  - Best coverage PC18M+20%XP2742 nanosilica
- Microtome examination effective means of coating thickness and coverage evaluation of complex layers
- Need improved liquid coating materials, application methods and process controls (e.g. updates to IPC standards) to assure improved coverage and thickness for tin whisker mitigation beyond humidity performance

Mixed and Reballed BGA Solder Joint Interconnect Reliability - CALCE

- **Mixed Solder BGA Conclusions**
  - **SAC BGAs may be reliably assembled in a tin-lead solder process provided sufficient temperature and/or time at peak temperature is allowed for mixing of lead (Pb) into the bulk solder joint.**
    - addition of lead (Pb) provides enhanced vibration reliability
    - consideration on an assembly level basis to assure that the adopted profile does not result in damage to other assembly devices
- **Reballed BGA Conclusions**
  - **The temperature fatigue life of lead-free BGAs reballed with SnPb solder balls is lower than lead-free BGAs assembled with tin-lead paste and lead-free paste under a -55 to 125oC temperature cycle. This result may be due to lower fatigue life of tin-lead as compared to lead-free solder.**
    - Temperature exposure should be assessed and controlled
    - Contamination levels should be measured for reballed parts
    - Solder ball attach strength under both pull and shear tests of tin-lead is lower than SAC but overall distribution of tin-lead solder is lower